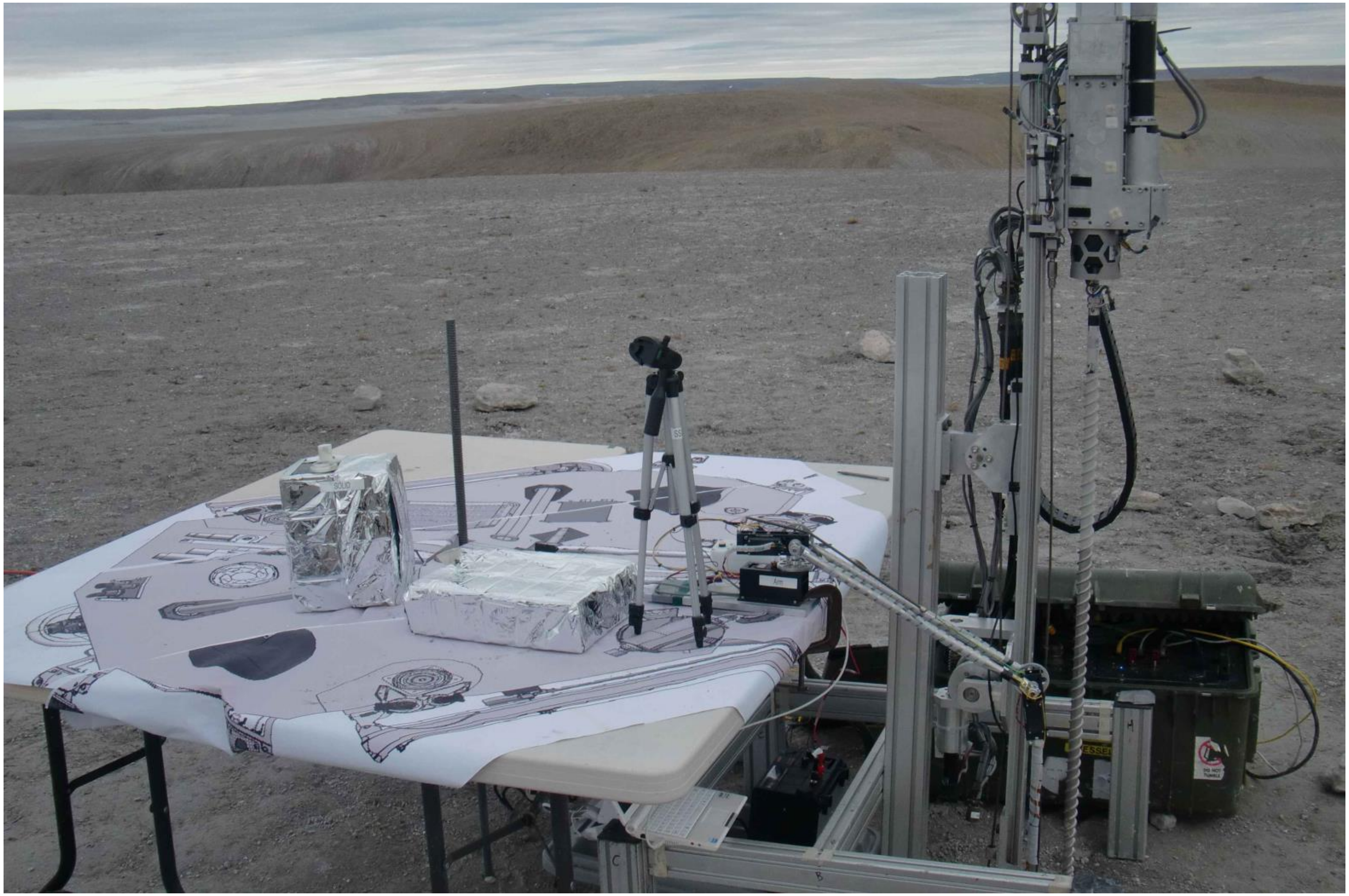
Mitigating Inadvertent Contamination in Subsurface Drilling



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Kris Zacny, Gale Paulsen, Honeybee Robotics

Why would we care about this?

- Human presence will bring contamination to Mars
- Human activities that drill into the subsurface:
  - Resource prospecting (last talk)
  - Science: sampling
  - Engineering (anchoring, foundations, sheltering)
- But the subsurface may harbor Special Regions where microbes could survive
- How do we (repeatedly) decontaminate our drill?

Developing and maturing 2m-class planetary drills, 2004-14

- Long-term NASA program of increasing drill technology readiness
- 2004-05, Rio Tinto, Spain (MARTE) – surface string changeouts and sample transfers, topside robotics
- 2006 Idaho (ATK/Swales) automated core retrieval and handling topside
- 2006, 2008 Haughton Crater (DAME) – downhole hands-off automated drilling and failure recovery, ice and hard rock penetration and coring
- 2009-10 CRUX rotary-percussive drill, intentional overnight freeze, recoded to run on flight boards
- 2011-12 Icebreaker-1 (32 kg, 2m capable) at Haughton, Jan 2013 in Antarctic Dry Valleys
- 2013 LITA Atacama drill (9kg) was too flexible and underpowered for ice-cemented ground at Haughton
- 2014 Redesigned Icebreaker-3 (12kg, 1m) drilled ice and hard rock with few issues at Haughton

MARTE at Rio Tinto 2005

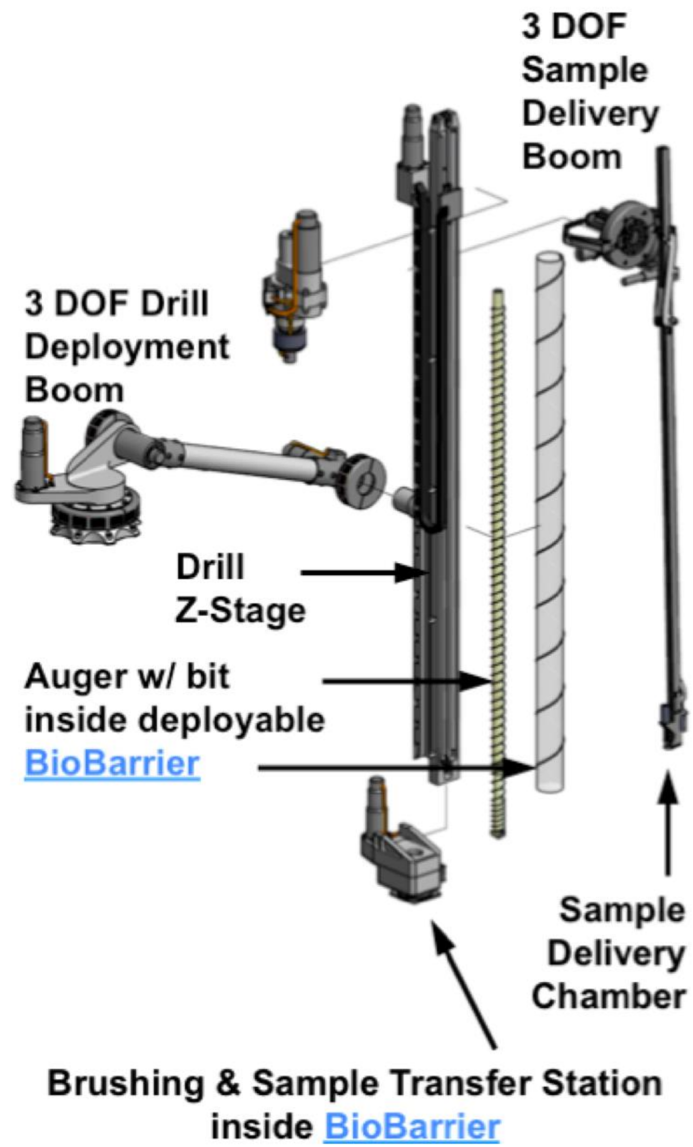
LITA at Haughton Crater 2013

Sample Surface Accumulation

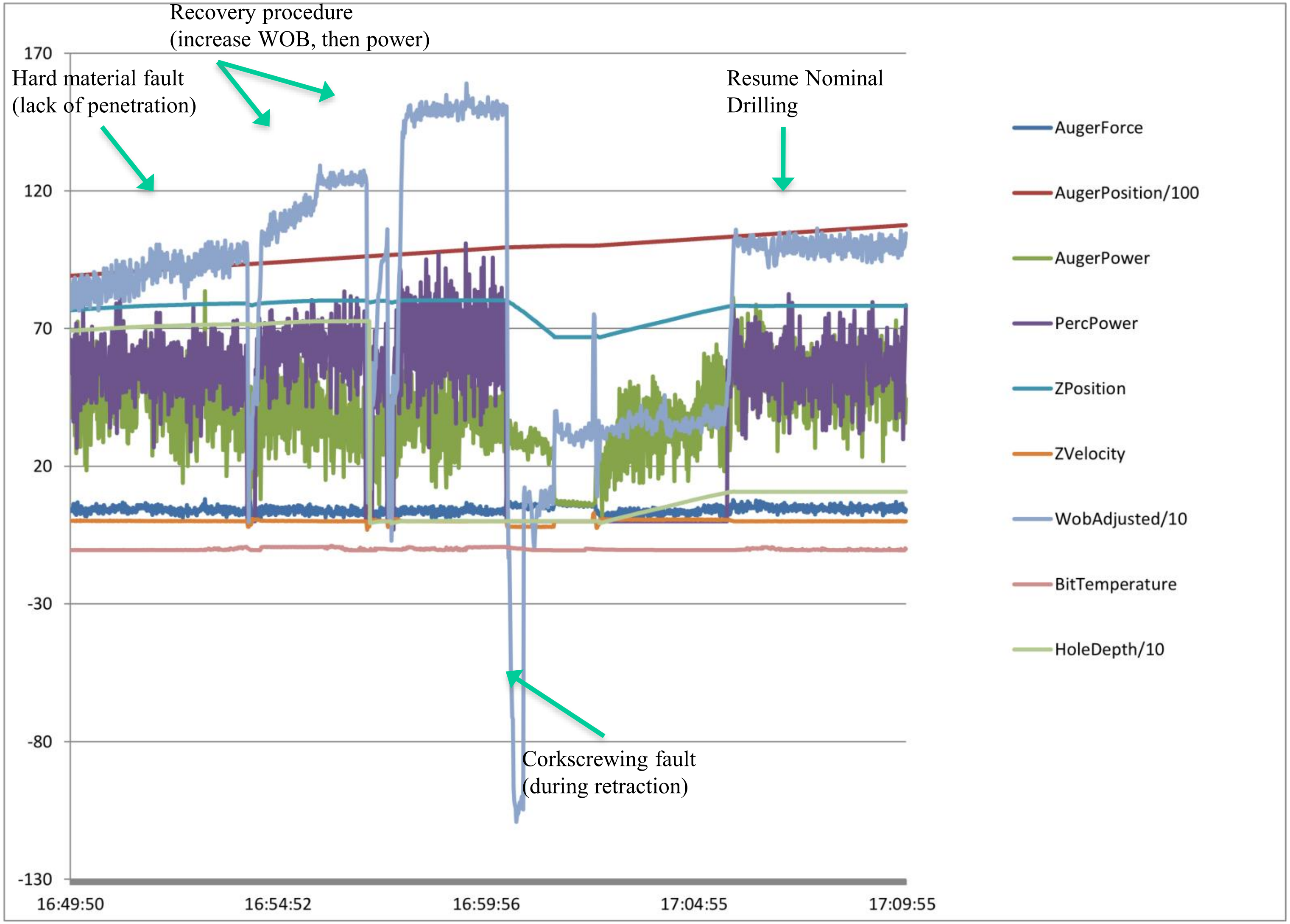
- Cuttings, vs core + crusher
- Drill in 5-10 cm “bites” where cuttings accumulate on the shallow auger flutes and brought up by retracting drill to deliver sample from a specific depth (not quantified)
- Passive deposit of cuttings into a consolidated surface pile - source of reverse contamination from SR below?

Drill – *Icebreaker* Prototype

- Icebreaker 12 kg drill prototype capable of rotary-percussive drilling in a vacuum
- Tested in chamber with deployable boom sized to fit Phoenix/InSight deck
- Total linear stroke of 1 m (1.3m string)
- Rotary and percussive actuators are max 200W each (50W nominal + margin) Maximum weight on bit is 100N
- Load cell is axially aligned with the drill segment to provide accurate feedback of drilling loads to the control software



Hard Material/Bit Wearout with Icebreaker Drill



Antarctica, University Valley, 25 Jan 2013

2011-14 Icebreaker Drill Field Test Results

5 of 6 major faults encountered naturally in drilling (choking was induced) with all correctly detected and four were automatically remediated (jamming, binding, hard material/bit failure and choking)

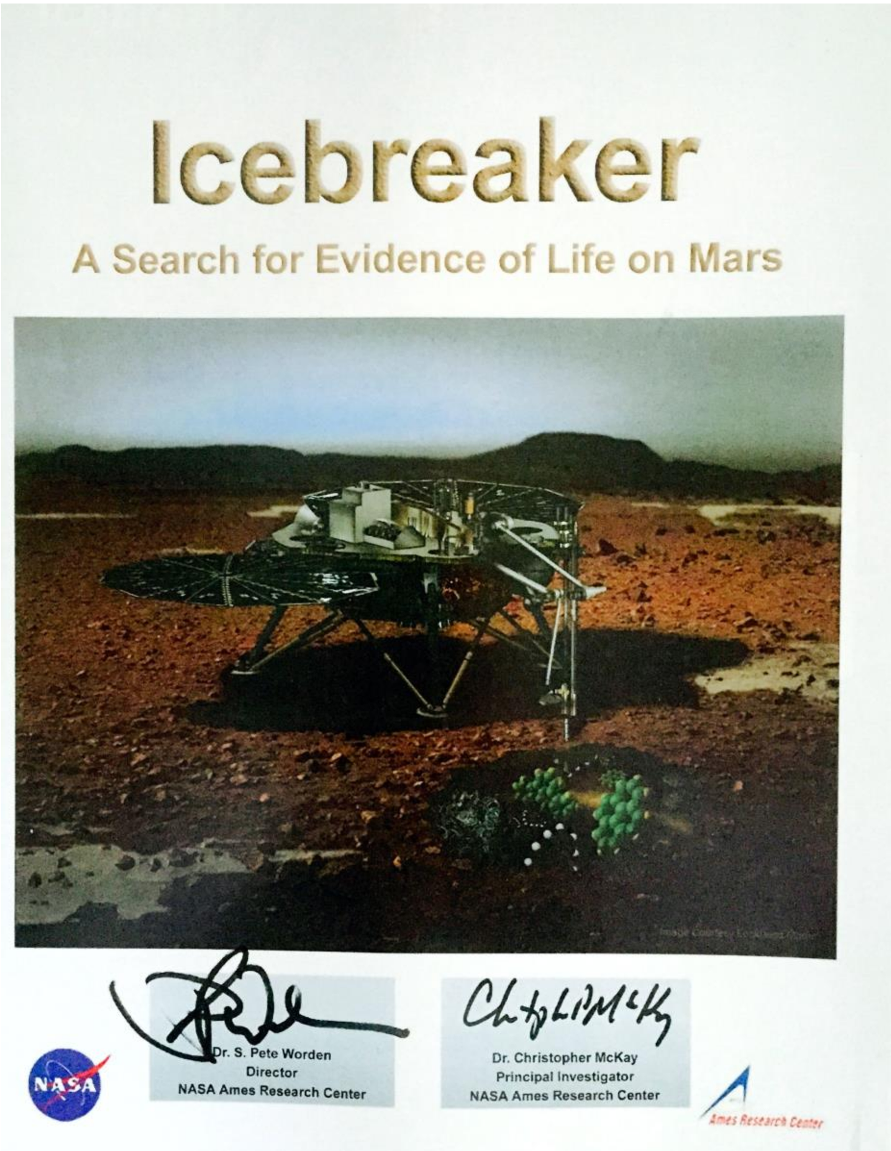
Hands-off, automated drilling demonstrated for hours-long sessions)

Depth over 11m cumulative in several holes, two were >2m depth each; all light/low-power (>100W/100N)

Lighter mass, lower downward force, lower power == less robust, requires more automated oversight and reaction to prevent faults

Automated, integrated sample acquisition and transfer demonstrated in cooperation with drilling operations

Icebreaker – Phoenix/InSight Follow-on Mission Proposal



- Discovery mission proposal
- Phoenix polar location
- InSight spacecraft bus
- Drill instead of scoop; SOLID replaces TEGA; sample transfer arm
- Organic compounds and life evidence focus (SOLID, WCL, laser desorption mass spec – MOMA derived)
- Partners:

Goddard Space Flight Center

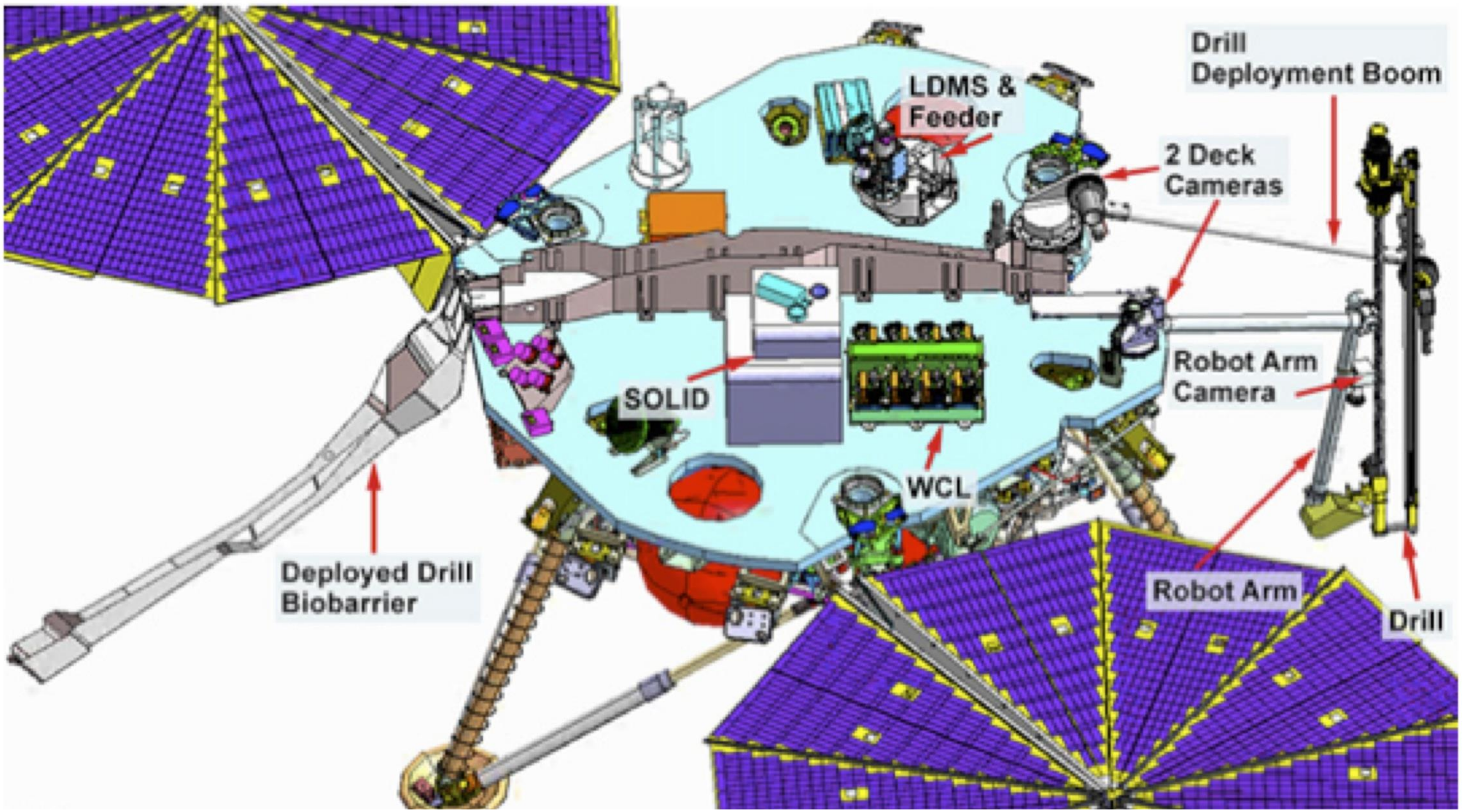
INTA

Lockheed Martin

Honeybee Robotics Spacecraft Mechanisms Corporation

JPL

Icebreaker Layout



NPS 8020.12 - Investigating Special Regions

5.3.2.3 PP Category IVc.

…

b. For missions accessing a special region though horizontal or vertical mobility, one of the following requirements shall be imposed:

EITHER

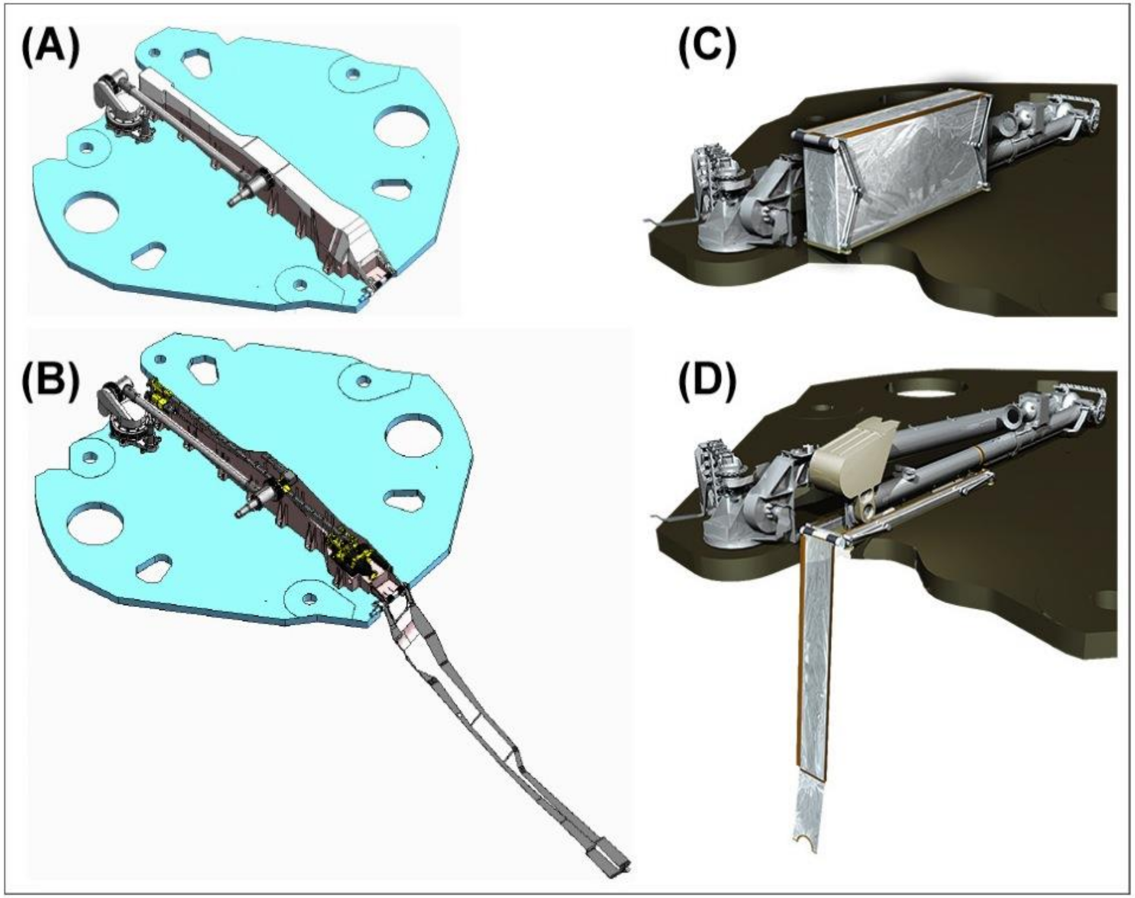
(1) The entire landed system is restricted to a surface biological burden level of 30 spores (see 5.3.2.4);

OR

(2) The subsystems which directly contact the special region are sterilized to these levels, and a method of preventing their recontamination prior to accessing the special region is provided.

Example – IB biobarriers for drill/arm

- Drill biobarrier shown closed lying across Icebreaker lander deck (blue) - A
- When opened, the biobarrier drapes over the deck - B
- Arm/scoop biobarrier closed C
- Arm/scoop biobarrier open - D
- (Note: drill and arm biobarriers are not shown at the same scale.)



Subsurface Knowledge Gaps

- How do we *not* contaminate acquired drilled subsurface samples?
- How can we recover during a mission if an accidental contamination of a drill does occur, if that drill otherwise accesses a Special Region?
- From NPS 8020.12, "preventing ... recontamination prior to accessing the special region" still applies **after** reaching Mars, so...
- Bigger issue than just drills – viz. scoops, crew shovels, tools, grading blades... Even survey poles

-> External or integral re-DHMRing capability

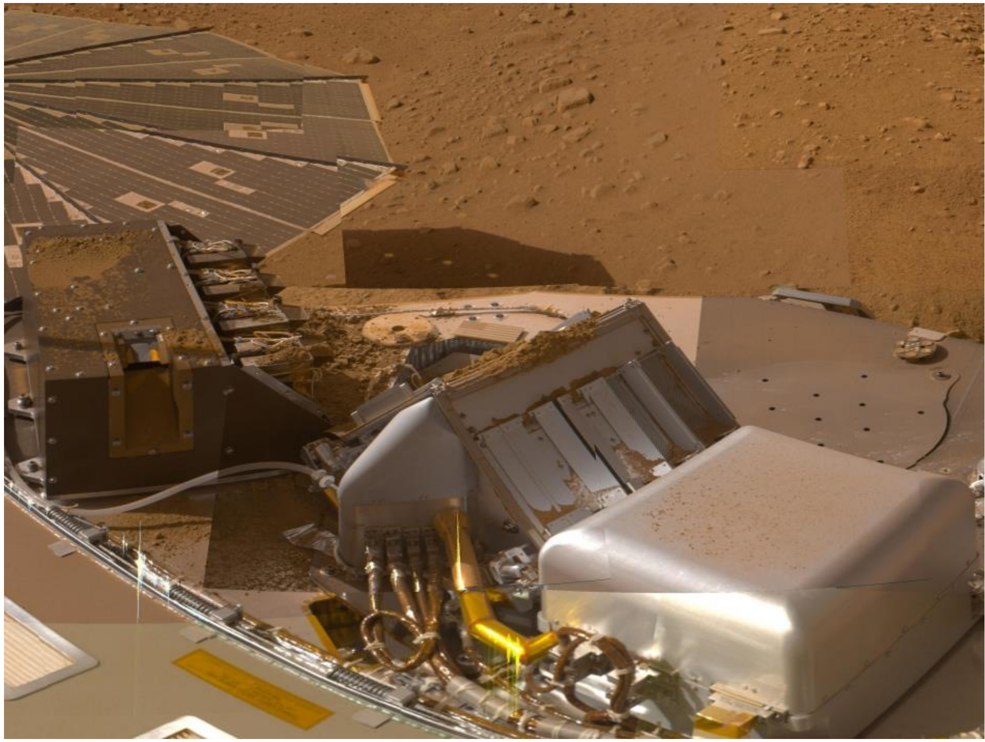
Some vector examples

(assuming a highly-cleaned drill transported to Mars in a biobarrier)

- Wind-blown particles off a lander deck
- Churned-up surface dust off a rover's wheel
- Failure to maintain a gap during sample transfer

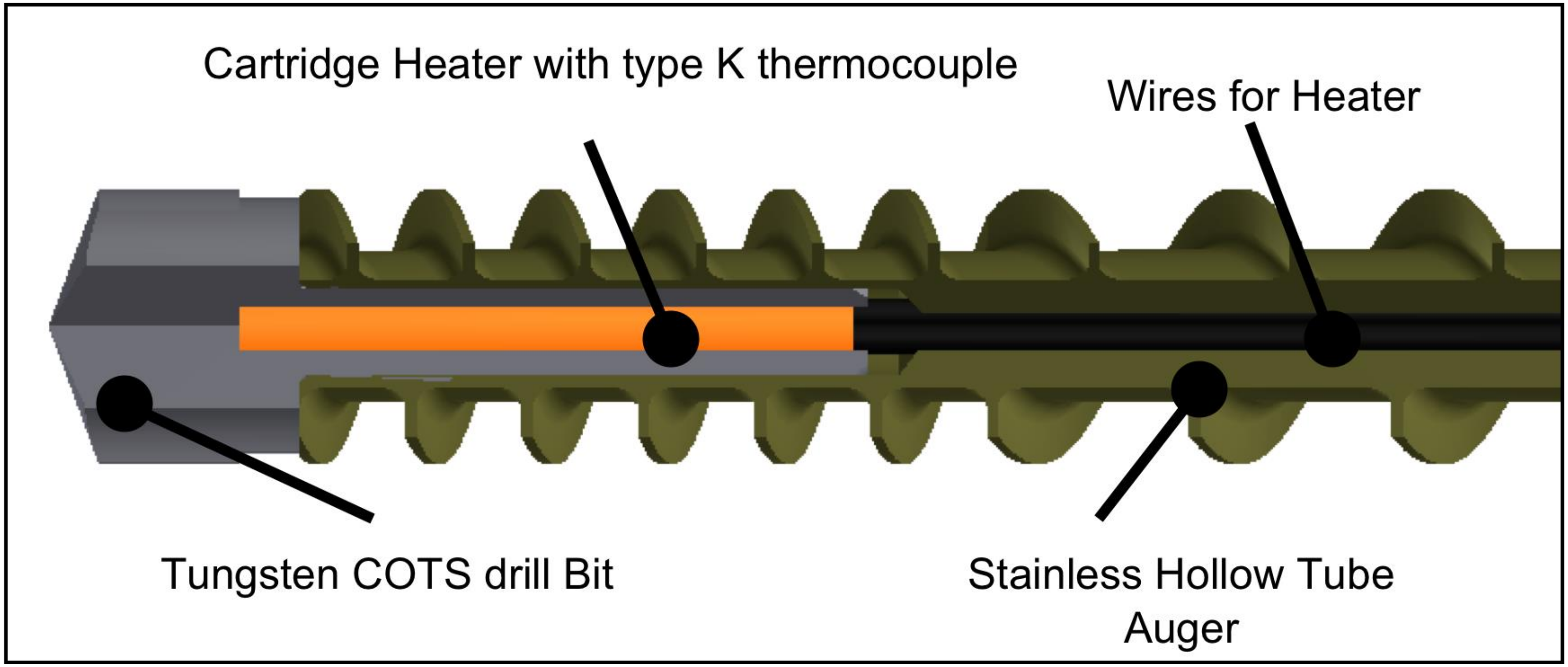
- Unintended contact with a less-cleaned surface (instrument inlets, robot arm, deck, crew gloves, etc)

- Human suit or hab venting nearby drill when it is on the surface (retracted or homed state)



JPL/UA/TAMU

Integrated Drill Heater Prototype



- 200W x TBD min, vs 50W x 20 min drilling cycle
- Cartridge heater rated up to 870 deg C (max)

Sample Transfer Testbeds

- Characterize the extent that acquired drill cuttings and subsurface dusts might contaminate the drill rig, other payloads or tools, and local surface terrain
- Dispersal of *Bacillus subtilis* or fluorescent latex microspheres
- Ambient, Mars-chamber, and analog sites
- Reverse and forward surveys

Summary

- Humans and robots will bring contamination to bodies with Special Regions (like Mars)
- We will also require subsurface access that may increase the likelihood of SR contact
- Contamination possible *after* landing and biobarriers removed
- Mitigate in-situ contamination risks:
  - Forward (drill heater for re-DHMR)
  - Reverse (subsurface dust survey and control)
- In-situ decontamination and sterilization technologies